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Unraveling the Mystery of Exozodiacal Dust

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Abstract. Exozodiacal dust clouds are thought to be the extrasolar analogs of the Solar System's zodiacal dust. Studying these systems provides insights in the architecture of the innermost regions of planetary systems, including the Habitable Zone. Furthermore, the mere presence of the dust may result in major obstacles for direct imaging of earth-like planets. Our EXOZODI project aims to detect and study exozodiacal dust and to explain its origin. We are carrying out the first large, near-infrared interferometric survey in the northern (*CHARA*/FLUOR) and southern (*VLTI*/PIONIER) hemispheres. Preliminary results suggest a detection rate of up to 30% around A to K type stars and interesting trends with spectral type and age. We focus here on presenting the observational work carried out by our team.

Keywords. infrared: stars, circumstellar matter, surveys, techniques: interferometric, techniques: high angular resolution

1. How to detect an exozodi

The thermal emission from hot exozodiacal dust (typically several hundreds of kelvin up to the sublimation temperature, e.g., Lebreton *et al.* 2007) results in a near-infrared excess above the stellar flux (typically 1% for known systems). This accuracy (at 3σ significance) is not reachable by simple photometry. It is necessary to spatially disentangle the dust and stellar emission. As the emission extends out to only a few hundred milliarcseconds for nearby stars, this is reachable only by interferometry. At short baselines ($\sim$10 to 40 m), considering fully extended (incoherent) dust emission around a nearly unresolved star, the emission results in a visibility drop compared to purely stellar visibilities that is equal to twice the disk/star flux ratio (Di Folco *et al.* 2007). Latest high precision near-infrared interferometers (*CHARA*/FLUOR, *VLTI*/PIONIER, Coudé du Foresto *et al.* 2003, Le Bouquin *et al.* 2011) allow us to detect this visibility drop.

2. An all-sky, near-IR survey for exozodiacal dust

We are carrying out the first large, near-infrared interferometric survey for exozodiacal dust (note the earlier results in the mid-infrared by Millan-Gabet *et al.* 2011). We are using the *CHARA*/FLUOR instrument in K band in the northern hemisphere and our *VLTI* visitor instrument PIONIER in H band in the southern hemisphere. A total of $\sim$ 200 stars are planned to be surveyed. The observing strategy and target selection is designed to form a large, statistical, and unbiased sample. A first sample of targets observed with CHARA consisting of 42 stars ($K < 4$ mag) has just been accepted for publication (Absil *et al.* 2013). The PIONIER sample (89 stars with $H < 5$ mag) has been observed and the data are under analysis (Ertel *et al.,* in prep.). Detection statistics for the CHARA sample are shown in Figure 1. Differences are most probably due to differences in sensitivity and lower excess in H band.

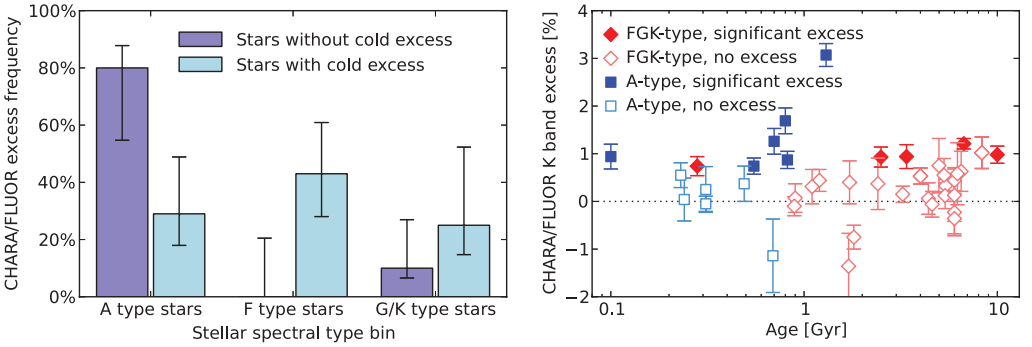

Figure 1. *Left: CHARA*/FLUOR K band detection rate of exozodiacal dust with respect to the spectral type of the host star and the presence or not of a cold, Edgeworth-Kuiper belt like debris disk. *Right:* K band excess as a function of stellar age.

Our magnitude limited sample allows for statistical investigation of correlations of the detection rate and excess levels with other parameters such as the stellar age, spectral type, or the presence of cold dust that could serve as a reservoir for replenishing the dust.

The most important results so far from the *CHARA*/FLUOR part of the survey (preliminary results from *VLTI*/PIONIER are largely consistent) are:

- The over all detection rate is $\sim 30\%$, for sun-like stars $\sim 20\%$.
- Stars with *and* without an outer reservoir harbor exozodiacal dust, but there *is* a correlation between the presence of cold and hot dust for sun-like stars.
- There is no significant correlation of the excess levels with the age of the star (Absil *et al.* 2013, Figure 1).

The latter would be expected in analogy to the well known trend in normal debris disks if the dust was produced in a steady state collisional process of larger bodies over the whole age of the system.

3. Future observational perspectives

The results from our survey as well as the state-of-the-art instruments and observing strategies allow for important and promising observational studies. Using *VLTI*/ PIONIER, and in the near future *VLTI*/GRAVITY and *VLTI*/MATISSE, the topics our team is currently working on include multi-wavelength observations constraining temperatures of known exozodis, the search for time variability of known exozodis on time scales of years, detailed studies of the hot dust in prominent debris disks, and the investigation of the connection between warm mid-IR and hot near-IR excesses.

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